ISSN 1330-3651
UDC/UDK 620.1.052:[621.822.1:621.89

THE DESIGN AND VERIFICATION OF EXPERIMENTAL MACHINE FOR REAL JOURNAL BEARINGS TESTING

Milan Kadnár, Jozef Kadnár, Sergej Hloch, Jan Valíček, Juraj Rusnák

Preliminary notes

The article presents the design of a machine for determining basic tribological features of real journal bearings. Thus, the article aims at presenting the principle of the machine and the kinematic scheme of the machine. The device is tested by a set of experiments with real journal bearings determined to be applied in automotive industry. The journal bearings on the base of bronze type B70 were tested. The experiment conditions resulted from the chosen application, steering servo unit.

Keywords: *bearing selection, testing machine, tribology*

Konstrukcija i provjera ispitnog stroja za testiranje stvarnih kliznih ležaja

Prethodno priopćene

U članku je prikazana konstrukcija stroja za određivanje osnovnih triboloških značajki stvarnih kliznih ležaja. Dakle, članak ima za cilj prikazati princip stroja i kinematičku shemu stroja. Uređaj je testiran na setu eksperimenata sa stvarnim kliznim ležajima s namjerom da se primjenjuju u automobilskoj industriji. Testirani su klizni ležaji na bazi bronce tipa B70. Eksperimentalni uvjeti rezultirali su iz odabranog primjera - upravljački servo uređaj.

Ključne riječi: *ispitni stroj, izbor ležaja, tribologija*

1 Introduction
Uvod

Determining tribological features of materials and lubricants seems to be simple due to exact examination of friction and wear processes. However, it is considered to be a complex task. The experiments of tribological features are realised on machines with different configurations in various laboratories. There exist many different types of experiments and those are only minimally normalised. Thus, it is very common that experiment parameters are selected according to the needs and demands whereby they respect only some regulations.

Each experiment is influenced by many factors. Each factor can influence an experiment in a different way. That is why there is no factor which can determine the friction or wear processes. Thus, there is no universal experimental examination of the friction or the wear.

Nowadays, there are many tribological experiments. Each of them is aimed at the examination of a partial tribological task or the experiment is realised under specific conditions [1-5].

It is necessary to interpret the results of a tribological experiment not from the point of view of a material itself but from the point of view of a material which is a part of tribological system. The material can behave differently in various conditions of friction or wear. The various tribological experiments can then have different range of materials [6].

In the majority of experimental devices, the real friction node is replaced by linear or spot contact. The values of friction coefficient cannot be compared with the values of real sliding nodes [2]. Thus, there is a minimum of experimental devices which are able to realise the experiment under the real sliding node and real process conditions. The construction of own experimental device provides the following advantages:

- the implementation of the newest measurement devices;
- the possibility to influence the range of process conditions;
- the complex knowledge of measurement, i.e. easy modifiability;
- the realisation of tight sliding node (several modes of lubrication), etc.

2 Radial journal bearing wear test rig
Oprema za ispitivanje trošenja radijalnog kliznog ležaja

The testing machine Tribotestor M'06 is aimed to fast determine the parameters and features of journal bearings [7]. It provides simulating different process conditions of sliding node if they are in the range of its technical parameters.

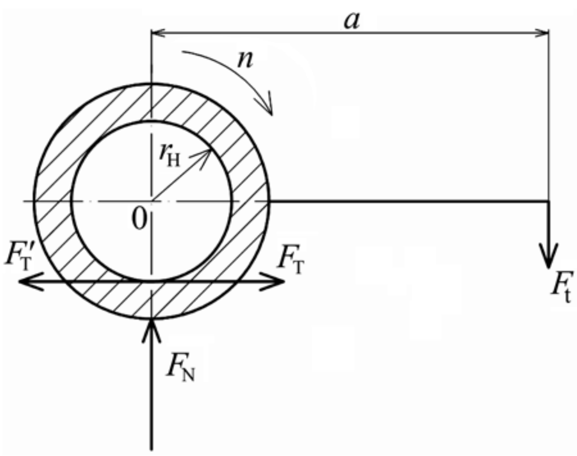
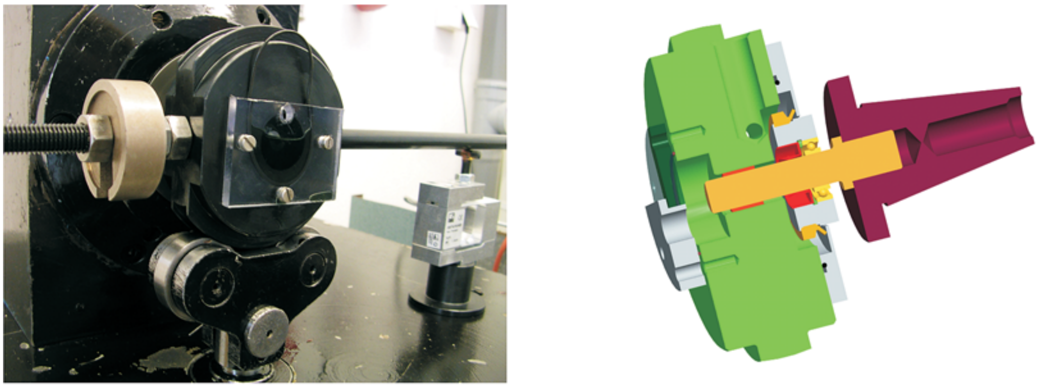


Figure 1 *The principle scheme of Tribotestor M'06 testing machine*
Slika 1. *Shema principa testnog stroja Tribotestor M'06*

The principle of friction factor measurement on Tribotestor M'06 testing machine results from the principle scheme illustrated in Fig. 1.

When the sliding node is loaded by normal force F_N, there is a friction between the shaft and the bearing



a) b)

Figure 2 *The real testing head (a) and the model of testing head (b)*
Slika 2. *Stvarna ispitna glava (a) i model ispitne glave (b)*

characterised by friction force F_T acting towards rotational movement of the shaft. The friction also causes the transmission of torsion moment to the head of testing machine (Fig. 2a), whereby the transmitted torsion moment is given by friction force $F_T' = F_T$ and the radius (diameter) of the shaft r_H.

The friction factor is derived from moment balance:

$$F'_T \cdot r_H = F_t \cdot a \tag{1}$$

where F'_T is:

$$F'_T = F_N \cdot \mu \tag{2}$$

that means:

$$F_N \cdot \mu \cdot r_H = F_t \cdot a \tag{3}$$

and so:

$$\mu = \frac{F_t \cdot a}{F_N \cdot r_H}. \tag{4}$$

The friction factor depends on:

- the force F_t measured at the end of testing head arm, N
- the length of testing head arm a, mm
- the normal load F_N, N
- the radius (diameter) of testing shaft r_H, mm.

The analogical solution of experimental device is represented by [2, 8, 9, 10].

The main technical parameters of experimental device Tribotestor M'06 are given in Tab. 1.

The analogical solution of experimental device is represented by [2, 8, 9, 10]. The main technical parameters of experimental device Tribotestor M'06 are given in Tab. 1.

Table 1 *The main technical parameters of testing machine*
Tablica 1. *Glavni parametric ispitnog stroja*

Parameter	Unit	Value
Diameter of sliding surface bearing	mm	10 – 30
Length of sliding surface bearing	mm	10 – 30
Shaft rotational frequency	rpm	0 – 6000
Loading force	kN	0 – 1
Maximum temperature of tested bearing	°C	300
Maximum friction moment	N·m	10
Temperature of working environment	°C	5 – 40

3 Experimental studies
Ispitna proučavanja

The following conditions were used during the friction experiments:

- diameter of shaft Ø10, cemented, hardened and edged – material ČSN 14 220; each shaft used only for one measurement;
- bearing clearance 0,02 mm;
- 6 samples of each material were tested;
- without lubrication.

The material B70 is a self-lubricant porous material on the base of sintered bronze. It is used in the process conditions with limited lubrication; suitable for static and dynamic load. It is produced by a technology of powder metallurgy. The chemical composition is given in Tab. 2.

Table 2 *Chemical composition of material B70*
Tablica 2. *Kemijski sastav materijala B70*

Material	Description	Element content			
		C	Sn	Others	Cu
B70	Sintered bronze	0,2 %	9–11 %	max 2 %	the rest

Table 3 *Phases of experiment during friction measurement*
Tablica 3. *Faze ispitivanja tijekom mjerenja trenja*

Phase	Time / s	Duration / s	Load / N	Revolutions / rpm
Stabilisation of sliding node	0	20	20	2000
Measurement with constant speed	20	120	100	2000
	140	120	150	2000
	260	120	200	2000
	380	120	250	2000
Stabilisation of sliding node	500	20	20	4000
Measurement with constant load	520	120	150	4000
	640	120	150	500
Support measurement for the control of measurement device	760	30	100	0
	790	30	150	0
	820	30	200	0
	850	30	250	0

The selection of experiment parameters is given by [11]. Based on the selected parameters, the complex

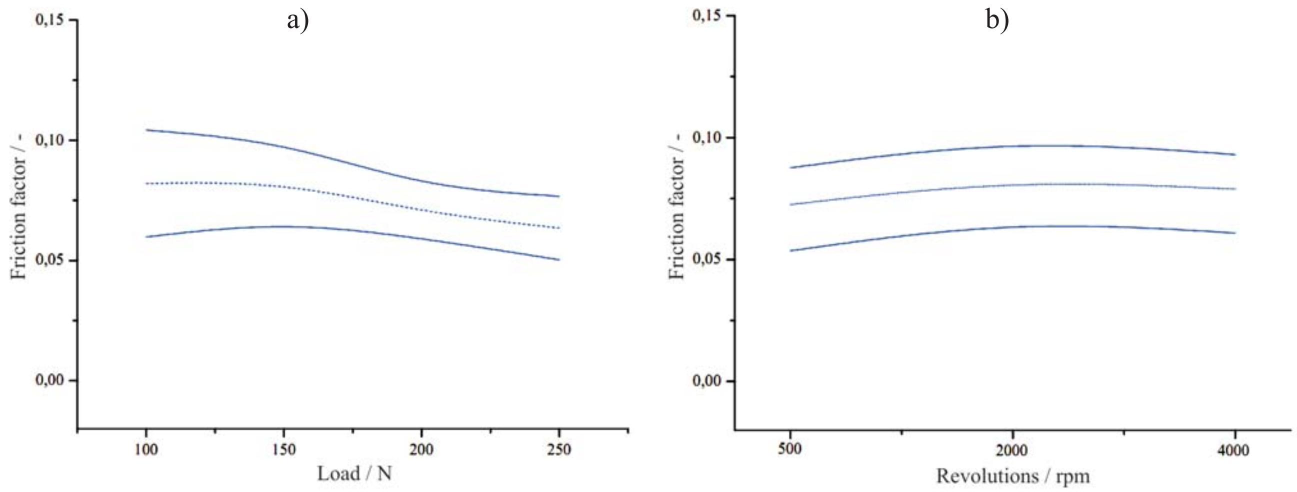


Figure 4 *The diagram of friction factor depending on load (a) and the diagram of friction factor depending on rotational frequency (b)*
Slika 4. *Dijagram faktora trenja ovisnog o opterećenju (a) i dijagram faktora trenja ovisnog o frekvenciji vrtnje (b)*

experiment of friction measurement was chosen. The experiment itself included multiple partial phases. Those phases are illustrated in Tab. 3. Before the experiment, each sliding node underwent a test run during 600 s with rotational frequency of 2000 rpm and the load of 150 N.

This phase was considered to be the preparatory phase and its results are not used in further experiment. After the test run each node underwent the stabilisation process, i.e. it was loaded by 20 N with rotational frequency of 2000 rpm. Consequently, the measurement was realised with constant rotational frequency of 2000 rpm and increasing loads of 100 N, 150 N, 200 N and 250 N. Each of described measurements was realised during the period of 120 s. Before measurements with constant loads, the sliding node underwent the next phase of stabilisation process during 20 s with the load of 20 N and rotational frequency of 4000 rpm.

The measurement with constant load was realised with the load of 150 N and the rotational frequency of 4000 rpm or 500 rpm. All the measurements of selected rotational frequency lasted 120 s. The diagram of the load or rotational frequency depending on time is illustrated in Fig. 3.

There are many statistical interpretations of friction measurement evaluation. For practical application of tribology, the table value of measured data is used rather rarely as additional information [1, 2, 5, 7, 8, 9 and 10]. The most important information is that which records the unfiltered record of friction force measurement. The rule

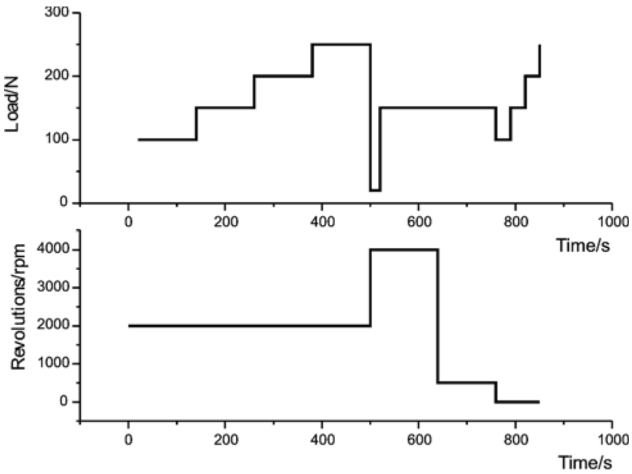


Figure 3 *The diagram of load and rotational frequency depending on time*
Slika 3. *Dijagram opterećenja i frekvencije vrtnje ovisno o vremenu*

that measurement values reflect the reality in tribological node is applied. The consequential data in the table or graphic illustration are only its interpretation. This article presents a compromise, i.e. a graphic interpretation with presentation of measurement values and confidence interval (95 %).

The final value of friction factor is not a measured value but the calculated value. Based on the used features of the steering servo unit, the rotational frequency was preferred rather than the circumferential speed.

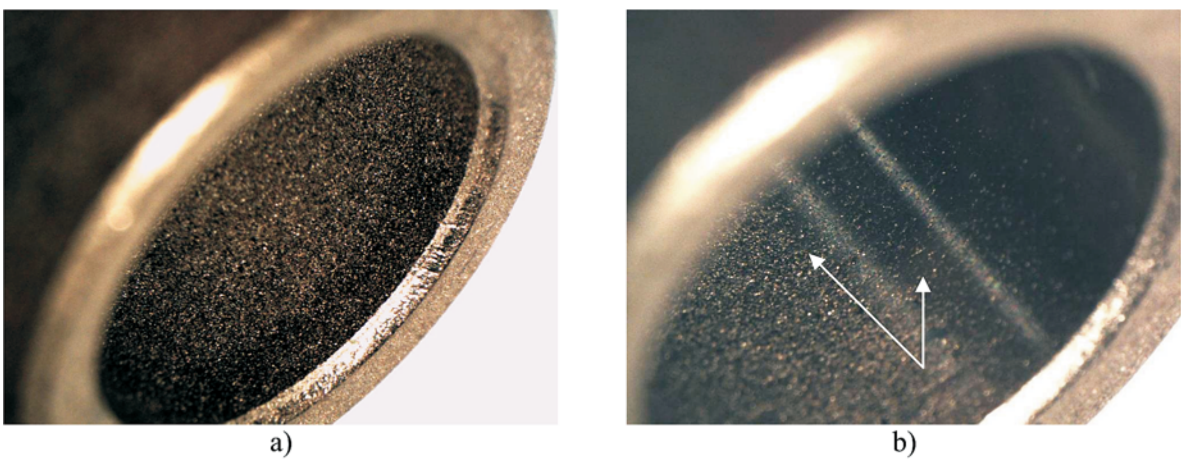


Figure 5 *Surface before the friction measurement (a) and surface after the friction measurement (b)*
Slika 5. *Površina prije mjerenja trenja (a) i površina nakon mjerenja trenja (b)*

4
Results and discussion
Rezultati i rasprava

During the experiment, little change of friction factor was marked whereby the diagram of friction factor depending on load is illustrated in Fig. 4a. Within the load of 100 and 150 N the value of friction factor was the same, i.e. 0,08. Consequently there was a drop to 0,07 when the load was that of 200 N. Finally, the measured value was 0,06 when the load was 250 N. When measuring the temperature of sliding node there were no significant differences, i.e. the temperature was approximately 40 °C all the time.

During the experiment with lower rotational frequency (500 rpm) and the load of 150 N, the value of friction factor was 0,07. The diagram of friction factor with constant load and different rotational frequencies is illustrated in Fig. 4b. When the rotational frequency was 4000 rpm, the friction factor increased to 0,08.

When measuring the friction, there were no significant differences in the operation of sliding node in testing machine. The examination of sliding material surface showed the marks of irregular wear (Fig. 5). Some parts of the surface conserved their natural features and the active parts remained smooth after the experiment. The sliding node of B70 material remained steady regarding the temperature and vibration. The weight drops were determined in the range from 7 to 12 mg.

5
Conclusions
Zaključci

The article presents the principle of realised tests focused on the determination of tribological features of real journal bearings. The experimental device was verified on the series of bearings made from sintered bronze. The repeatability of results points to the suitability of the test rig and the method. As the references show, based on the dry test conditions, the high values of friction coefficient were reached. The tested bearings behaved steady depending on the change of load as well as the rotational frequency. In the future there is a possibility to verify tribological features of so tested bearings also under the conditions of fluid friction whereby the construction of testing head allows the circulation of lubricant and additional influence of sliding node temperature which lets better simulation of real process conditions.

6
References
Literatura

[1] Mang, T.; Dresel, W. Lubricants and lubrication. New York: Wiley; 2001.
[2] Bayer, G. R. Mechanical Wear Prediction and Prevention. New York: Marcel Dekker, Inc., 1994.
[3] Czichos, H.; Habig, K. H. Tribologie (Tribology) – Handbuch. 2. Auflage. Wiesbaden: Friedr. Vieweg & Sohn Verlag, 2003.
[4] Stachowiak, G. W. et al. Experimental Methods in Tribology. Amsterdam: Elsevier Science, 2004.
[5] Stachowiak, G. W. Engineering Tribology. Third edition. Oxford: Elsevier Butterworth-Heinmann, 2005.
[6] Bhushan, B. Principles and applications of tribology. New York: John Wiley & Sons Inc., 1999.
[7] Kadnár, M.; Rusnák, J. Ekologické oleje aplikované do oblasti klzných uložení : metódy, prístroje a interpretácia : monografia (Ecological oils applied into the journal bearings: methods, devices and interpretation: monograph). 1st edition. Nitra: Slovak Agricultural University, 2008.
[8] Ünlü, S. B.; Atik, E. Determination of friction coefficient in journal bearings. // Materials & Design. 28(2007), pp. 973-977.
[9] Bhushan, B. Introduction to Tribology. New York: John Wiley & Sons, 2002.
[10] Rusnák, J.; Kadnár, M.; Kučera, M. Biologicky odbúrateľné oleje z pohľadu ich tribologických vlastností: metódy, prístroje a interpretácia: monografia (Bio-decomposable oils from the view of tribological features: methods, devices and interpretation: monograph). 1st edition. Nitra: Slovak Agricultural University, 2009.
[11] Kadnár, M. et al. Voľba kĺzneho uzla pre posilňovač riadenia. (The selection of sliding node for steering servo unit) 50th International scientific conference of departments of Machine Design): Terchová, 8th – 10th September 2009, Žilina (Slovakia): EDIS, 2009.

Authors' addresses
Adrese autora

Associate Professor Milan Kadnár, PhD
Faculty of Engineering
Slovak University of Agriculture in Nitra
tr. A Hlinku 2, 949 01 Nitra
Slovakia
milan.kadnar@uniag.sk

Jozef Kadnár, PhD candidate
Faculty of Materials Science and Technology
Slovak University of Technology
Paulínska 16, 917 24 Trnava
Slovakia
jozef.kadnar@gmail.com

Associate Professor Sergej Hloch, PhD
Faculty of Manufacturing Technologies
Technical University of Košice
Bayerová 1, 080 01 Prešov
Slovakia
sergej.hloch@tuke.sk

Associate Professor Jan Valíček, Ph.D.
Faculty of Mining and Geology
VŠB–Technical University of Ostrava
17. listopadu 15/2172, 708 33 Ostrava-Poruba
Czech Republic
jan.valicek@vsb.cz

Professor Juraj Rusnák, PhD
Faculty of Engineering
Slovak University of Agriculture in Nitra
tr. A Hlinku 2, 949 01 Nitra
Slovakia
juraj.rusnak@uniag.sk